ENVIRONMENTAL SUSTAINABILITY OF MARGINAL SOILS BY MISCANTHUS CULTIVATION: A REVIEW

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ABSTRACT

The paper discusses the possibilities of cultivating and using bioenergy crop in order to reduce climate change and protect the environment. Miscanthus is a perennial plant which annually produces great biomass of good quality and calorific value for energy. In addition to obtaining the second generation of fuel from its biomass, a new chemical conversion technique produces a product whose application can improve the quality of marginal soils. Based on the reviewed results, it was concluded that on marginal soils it is possible to plant the miscanthus seedlings and achieve expected yields. The Republic of Serbia has a large area of soil that could be used for this purpose, so it is recommended that additional research can be conducted to investigate the potential use of biochar in repairing this type of soil.

INTRODUCTION

Cultivation conditions

It originates from an area of temperate continental climate and the successful growth and development of plants require heat and large amounts of water. It uses absorbed water more efficiently than most arable crops, but under unfavorable water conditions, plant growth is limited, especially in the year of establishment. In the initial years, apart from optimal water supply, nitrogen nutrition has a major impact on biomass yield [1]. Irrigation of crops also increases the effect of the nitrogen nutrients used. Well formed plantation in the years of commercial exploitation has a strong deep-rooted root system and can absorb water accumulated in deeper soil horizons/layers.
Frost tolerance is also a cultivar trait, so that the newly introduced interspecies *Miscanthus x giganteus* hybrids tolerate winter frosts and cold weather in the spring better than native varieties and populations originating in the Far East [3].
Miscanthus grows and yields satisfactory yields on soils of various properties, from sand to soils with a high organic content [4, 5]. This energy crop can be grown under different agro-ecological conditions, but the value of biomass yield is greatly influenced by weathering during the growing season [6].

Production technology

As a perennial plantation, miscanthus is grown outside the crop rotation, and once planted it is used for 15-20 years. All agrotechnics can be performed by standard agricultural machinery [1]. The surface on which the planting is to be done should be prepared as for other agricultural crops. Plants use the nutrients very rationally by moving assimilants from the

underground to the aboveground organs during the growing season and returning them to the rhizomes before winter. Planting can be done in mid-April, when the danger of spring frosts passes, or in October. Planting requires 10,000-20,000 rhizomes per hectare [7]. In early years, a greater number of plants per unit area has the advantage of facilitating weed control [8]. Depending on the way of use, the biomass harvest using forage harvester is in period when the plants have reached the maximum height - at the end of August and the first half of September (for biodiesel or bioethanol) or during the winter when the miscanthus trees have the least water (for solid fuel) [9].
From the second year, the yield increased significantly, reaching its highest value after the third year. In the years of maximum production, over 100 t ha^{-1} of fresh biomass (trees and leaves) and 15-25 t ha^{-1} of dry trees can be obtained, and in very favorable weather conditions, or with irrigation, over 30 t ha^{-1} can be obtained, with about 30% of water.

The transition to renewable energy and rehabilitation of degraded soils have been a topic of great interest in recent decades, thus for these purposes can serve plant species that have high annual biomass production, resistant to biotic and abiotic stress and require minimal investment in agrotechnics [7].
The cultivation of miscanthus on fertile soil is an irrational use of the potential of such a resource. To avoid conflict over the choice of plant species to use the most fertile soil between the needs for food production or for bioenergy production, it is recommended that marginal soils should be used for bioenergy crops. The marginal soils are usually described as unproductive or unsuitable for crop production due to poor soil properties, poor groundwater quality, drought, undesired topology, unfavorable climatic conditions, usually having no or little potential for profitability for conventional food crops [10]. Also, marginal soils include brownfields, previously contaminated soils, fallow agricultural soils due to unfavorable crop production conditions, degraded soils, or landfills [10]. The total area of arable and arable soils on the territory of the Republic of Serbia that could be suitable for cultivation of bioenergy crops is 2,462,529 ha [11].

PREVIOUS RESULTS AND DISCUSSION

Soil quality, organic matter concentration, and organism diversity are enhanced by growing miscanthus in contaminated and marginal soils [12]. The same authors point out that miscanthus has potential to stabilize and possibly remove metal contaminants slowly over time while being grown for its energy value. The effect of different doses and types of fertilizers on the yield of miscanthus cultivated on soils with limited production capacity (marginal soils) has been examined [13]. The results of the survey did not show a statistically significant impact of the applied fertilizers and the average yield in the year after planting was in the range 2.1-2.7 t ha^{-1}. Adverse climatic factors during the planting period and soil type resulted in low yields. Miscanthus cultivation is possible on marginal soils such as gleysols, planosols and technosols, with minimum application of agricultural measures only during the year of establishment. Due to favourable water conditions, gleysols may be recommended for miscanthus production [14].
A satisfactory average biomass yield (5.78 t ha^{-1}) was achieved on deposols with a significant difference between years [7]. Other authors also stated the possibility of establishing miscanthus and phytostabilization of ash and slag landfills, as the technogenic substrate extremely unfavorable for plant growth, by using this species [15]. Improved ecosystem services and low production costs justify lower miscanthus biomass yields in marginal agricultural sites [16].

Miscanthus use

Miscanthus represents a key candidate energy crop for use in biomass-to-liquid fuel-conversion processes and biorefineries to produce a range of liquid fuels and chemicals [17]. Miscanthus biomass application is primarily related to the production of second generation biofuels. An analysis of the biomass of miscanthus cultivated in the territory of Republic of Serbia yielded calorific values from 14.9 MJ kg^{-1} to 18.3 MJ kg^{-1}, indicating that it is promising to introduce biomass of miscanthus as a renewable energy source [18, 19].
Using various thermochemical processes it possible to obtain a range of products that can also be used in agriculture. One of these products is biochar. Pyrochar and hydrochar differ in their physicochemical characteristics depending on the production process and the feedstock [20, 21]. Miscanthus can be a good raw material for biochar production because of the high yield and energy it generates at generally low investment requirements. Miscanthus biomass at harvest time is low in moisture content, which also reduces the cost of char production [20].
Promising results are shown by a relatively new process called hydrothermal carbonization (HTC) of biomass, where biomass is treated with hot compressed water instead of drying [19, 20]. The HTC process offers several advantages over conventional dry-thermal pre-treatments like slow-pyrolysis in terms of improvements in the process performances and economic efficiency, especially its ability to process wet feedstock without pre-drying requirement [20].
Hydrothermal carbonization in the temperature range from 180 to 220°C for 60 minutes is effective for obtaining miscanthus hydrochar. In terms of chemical and fuel properties, the hydrochar obtained at 220°C was the best demonstrated [22].
The use of biochar in agricultural practice to improve soil properties has shown a number of positive effects on water and nutrient retention capacity, reduction of volatilization of nitrous oxides, leaching of nitrates from soil, efficiency of applied fertilizers and productivity of cultivated plants [23]. It also has carbon sequestration capability [20], which contributes to the reduction of greenhouse gas emissions. The use of biochar in combination with phytoremediation techniques is a challenge for future research, since their interaction has the potential to remediate the soil contaminated with heavy metals [24]. *Miscanthus x giganteus* hybrid has the potential for both techniques (biochar feedstock and plant for phytoremediation).

CONCLUSION

Miscanthus cultivated on marginal soils does not compete for food production. According to the aforementioned data, the Republic of Serbia has sufficient land area that could be used for the cultivation of energy crops for the production of second generation biofuels. In addition to the positive impact of miscanthus cultivation on the soil condition and quality, using relatively new biomass processing technologies for this energy species the products of an exceptional importance are obtained, and they can, on the other hand, enhance the quality of marginal soils. The lower productivity of miscanthus on marginal soils is offset by improvements in the entire ecosystem and low production costs. In Serbia, commercial cultivation of miscanthus is represented on small areas, and the results presented in the paper on the yield of miscanthus are a part of the research that examined the possibility of its production on marginal soils.
The results presented refer to the first years after rhizomes planting on soil with poor properties, which has longer planting time compared to planting on fertile soil. It is to be expected that they will be higher and justify the investment over many years of plantation life, but what is more important is the fact that even in extremely unfavorable soil conditions the establishment of this bioenergy crop is possible. It is necessary to continue with this type of

research before reaching concrete conclusions and proposals for commercial cultivation, since in addition to the type of soil, weather conditions, that are very unstable in recent years, have an extreme impact. It would be environmentally and economically justifiable to invest in research which would include the use of biochar for the purpose of rehabilitation and reclamation of an agricultural soil, since previous research has shown that such a technique has the potential.

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